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SEMANTIC CATEGORIES OF NOMINALS FOR CONCEPTUAL DEPENDENCY ANALYSIS OF NATURAL LANGUAGE

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SEMANTIC CATEGORIES OF NOMINALS

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CONCEPTUAL DEPENDENCY ANALYSIS OF NATURAL LANGUAGE

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ABSTRACT: A system for the semantic categorization of conceptual objects (nominals) is provided. The system is intended to aid computer understanding of natural language. Specific implementations for "noun-pairs" and prepositional phrases are offered.

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1. Introduction

The purpose of this paper is to discuss the basis for a system of categorization of conceptual objects or nominals, and to show how such a system might be useful in computer understanding of natural language. The level of understanding with which we are concerned is principally the ability to form a conceptual representation of an isolated input sentence which "makes sense". As we are for the present more interested in the capabilities of a parser rather than of a question-answering system, we will regard as important that which is conceivable rather than that which is true or usual according to our cultural experience. At the same time, we recognize that cultural experience and other levels of information would certainly be of use to a parser in its advanced stages and will be seen to touch on the level we are considering at various points.

The discussion and the terminology used will in particular relate to Schank's conceptual dependency theory (7), although the ideas expressed are not completely dependent on that theory. Most of the theory to be described has actually been implemented in the semantic subprograms referred to in Sections 4.3 - 5.3, which were designed to operate in conjunction with the conceptual parser being developed at the Stanford Artificial Intelligence Project (8).

We will begin our discussion with some considerations as to why categorization is necessary, what we want to keep in mind while categorizing nominals, and what form our categorization will take. Section 3 establishes basic nominal categories and points out characteristics of nominals which play a role in determining dependencies which are observed to hold between such nominals.

In Section 4 this information is formalized in a specific category system and incorporated into a semantic dictionary. Finally, Section 5 discusses specific implementations of the procedure for using the resulting dictionary descriptions in the interpretation of "noun-pairs" and prepositional phrases.

2. Motivations underlying Categorization

2.1. Reasons

Western man is frequently designated as an avid clasifier; he wants to "put things into boxes". While not taking a position on this type of description of reality, we can surmise that communication presupposes some notion of three categories of concepts at the cognitive level--conceptual objects, conceptual attributes and conceptual relations together with associations between these on the basis of the particular characteristics of the concepts involved. These associations become more narrowly restricted by cultural experience. A human being knows that certain concepts "go with" other concepts in certain ways. If one concept serves to describe or qualify the other, a dependency can be identified. Since the average sentence contains more than two concepts, the hearer must be able to make a choice as to the rule of the concepts and the possible dependencies. In practice, he is aided by the syntax of the language.

However, in the case of e.g. the "dangling participle" (Schank's 'John saw the Grand Canyon flying to New York') or of a triple-noun sequence ('pipe organ theater'), syntax cannot resolve the ambiguity. Furthermore, resolution of the latter example involves the necessity of reconstructing missing information. One cannot group two nominals together without knowing why, i.e. without understanding, at least subconsciously, through what other concept they are dependent. 'Pipe organ' cannot be represented analogously to 'kitchen table'. In order to be able to recognize the "meaning" of such a construct, we must rely on dependency information. As we obviously do not wish to note explicitly all the conceivable dependencies existing between individual concepts, we need to classify such concepts, while noting the dependencies which exist between the various classes.

2.2. Approach

A "valid" category scheme must be based on something more intuitive and interdisciplinary than an exclusive reliance on observable linguistic data. We would like a system which could provide a basis for discussion, with an eye to expansion and improvement, and which could benefit from philosophical considerations and psycho-linguistic experiments. Dealing at the conceptual level as mentioned above, rather than at any syntactic or "deep-structure" level, is certainly a prerequisite to fulfilling such conditions. More specifically as regards the question of semantics, the conceptual approach is much more powerful than the syntactic approach in recognizing equivalent phrases which have different and perhaps complicated syntactic forms. For instance, 'a piano in the basement' would have the same representation as 'a piano occupying the basement' at the conceptual level, for both examples express relations between nominals, where the second nominal is involved in a qualifying dependency on the first.

The conceptual classes mentioned above, then (nominals, attributes, relations), are the ones we consider subject to further categorization. They correspond to the PP, PA, and ACT of Schank (7) respectively, and sometimes map into nouns, adjectives and verbs. The assignment of a group of concepts into the same (sub-) category (however such a category is defined) implies that these concepts have the same conceivable dependencies on them and that they are intuitively similar with respect to some basic feature.

As in this paper we will be concerned mainly with the categorization of nominals (ACTs or verbs will be discussed in (6)), we might give a rough indication as to what we consider not to be a conceptual nominal, since almost anything can be "nominalized" syntactically. English has nouns for complicated situations, such as 'involvement', which are clearly not objects in the sense that 'book'

or even 'air' is. Nouns such as 'involvement' represent complex conceptual structures in themselves. We will not consider them in our classification scheme, but will note only that they form a major class of nominals with their own selectional restrictions at a higher or "meta-" level.

2.3. System

Much reference has been made to a role for hierarchies of categories in semantic analysis. It is obvious, however, that the set of all possible distinguishing characteristics used as criteria for branching in a tree-structure will apply to high-level categories in various combinations to produce low-level subcategories. The result is overlapping categories, i.e. categories which each have members which share a characteristic which alternatively could have been used to set these members apart as a category. To use a simple example, if a non-terminal category called 'object' can be further subdivided according to color (black or white) or shape (square or round), and color is chosen as a node criterion, then a further branching according to shape will have to be applied to both the black and white subcategories at the next level, or to four new categories if branching according to another criterion intervenes, etc. Thus undesirable redundancy results.

A realistic reaction to an explicitly hierarchical system is presented by Arnheim (1): "Each individual thing would be explicitly assigned to as many groups as there are possible combinations of its attributes. A cat would be made to hold membership in the associations of material things, organic things, animals, mammals, felines, and so forth, all the way up to that exclusive club for which only this one cat would qualify. Not only this, but our cat would also belong among the black things, the furry things, the pets, the subjects of

art and poetry, the Egyptian divinities, the customers of the meat and canning industries, the dream symbols, the consumers of oxygen...".

This example suggests that a detailed set of hierarchical categories would be so inconvenient as to be unusable. A feature system is in many cases more adapted to the extraction of information about the concept. Thus instead of having to classify an item as belonging to category A and category B (C, D, ...) by virtue of having feature x, we can simply mark the item as "+" with respect to feature x. If, however, the number of features to be filled in is large, this system too will be, if not redundant, at least tedious to implement. We assert that the number of features critical to dependency information for any given concept is relatively small. This system will also be more flexible, since by dealing with individual features rather than with categories, we are dealing with the items of information about a concept directly rather than through the overall similarity of the concept to another object in the same class. The semantic component of a parsing program will thus be far more manageable. Another pragmatic advantage of using semantic feature descriptions of lexical items occurs at the time of entry into the dictionary, as will be shown.

3. Nominals

3.1. Nature of the Classification

Considering the categorization of nominals, we note that the dependencies on nominals will be of three general types (our examples will be in terms of dependencies which are qualifying rather than predicative): attributive (which describes the inherent properties of the nominal concept, i.e. what the concept is), e.g. 'tall boy'; active (which describes the temporary properties of the concept, i.e. what it does--with or without other concepts), e.g. 'barking dog'; and relational (which describes its possible static relation to other nominals), e.g. 'dog on the chair'. Using Schank's conceptual categories, these dependencies could be represented as $\begin{matrix}PP\\ \uparrow\\ PA\end{matrix}$, $\begin{matrix}PP\\ \uparrow\\ ACT\end{matrix}$ (or if there is another object involved, as $\begin{matrix}PP & \\ \uparrow & \\ ACT & \leftarrow PP\end{matrix}$), and $\begin{matrix}PP\\ \Uparrow\\ PP\end{matrix}$ respectively. Since we will be using our category information for resolution of dependencies, our decision as to how a concept should be formally described or categorized should be guided in part by dependencies which we observe to be associated with the concept.

Our approach will be to establish some high-level or "major" categories on the basis of what are thought to be conceptual primitives and on the basis of some observations about the physical world as perceived by a human being who understands reality only through his senses and "everyday" language, i.e. without the aid of any analytic scientific discipline. These categories will be conceptually different from one another in some obvious way. A brief discussion on each category should reveal what other semantic features are relevant and critical to a useful description of individual concepts in that category. As we seek to "scan the whole world of concepts", it is of course an understatement to say that no pretense to the completeness of the model will be made.

3.2. Major Nominal Categories

The major categories decided upon follow, together with some indications as to why they suggested themselves. It will be noted that some of the categories considered are not strictly PPs, since they will appear in a different form in a conceptual diagram. However, we wish to acknowledge their nature, giving them a place in our world model so that we might indicate how these nominals fit into a conceptual diagram. The major categories will be discussed in terms of three groups, although this grouping is not significant to the implementation.

3.2.1. Basic Framework

The first group consists of just one category, called BASIC, containing only two items -- (some) '$space_1$' and (some) '$time_1$', and any synonyms, e.g. one sense of 'room'. They are unique in that they are inherently "empty"; i.e. 'no space' implies matter, 'no time' implies something is happening. Such implications can be of use to a program which makes inferences on the basis of a conceptual diagram involving these concepts. For instance, if a parser is to be embedded in a dialogue program, the statement 'I never have any time', if correctly represented by the semantics as involving the BASIC '$time_1$', would reasonably evoke the response 'What do you do all the time?', rather than any one of a number of responses recognizing lack of possession. Likewise, 'There is no space' would reasonably lead to a question as to what is taking up all the space. Since matter and happenings or events are what "fill up" our physical world by occupying space and time in some way describable e.g. by location, size, time, duration etc., the BASICs are a kind of framework for our conceptual model of the world and of language.

3.2.2. Applied Properties

The second group of major categories concerns the "content" or "properties"

applied to items in the BASIC group, as well as some properties applicable specifically to animate objects or humans. The first two categories in this group are MATTER and ACTION. MATTER is that which physical objects (a class of PPs) are made out of; ACTION is that which temporal objects (events) are made out of. MATTER has both abstract and concrete characteristics. That is, in 'rubber ball', 'rubber' is the material aspect of the 'ball'; it does not exist independently of the ball, and is thus an abstract property. However, we could conceive of rubber existing independently of any recognizable discrete object, in which case it would be considered concrete.

An example of ACTION would be 'baseball', as in 'baseball game'. Note that this is not exactly the same thing as what Schank means by a conceptual ACT (7). An ACT, e.g. 'play', can be done by some actor (object or group of objects). An ACTION is a complex concept which involves actors and characterizes an ACT. However, as it is a temporal concept, it is not a true PP either, although it appears syntactically as a nominal. The relationship of ACTs to ACTIONs will be illustrated in conceptual representations of certain types of phrases (Figure 3).

The third category (PHEN) of this group reflects the fact that our physical world consists not only of visible MATTER, but also of certain "phenomena" or "conditions" having both physical and temporal components. Some examples are describable physical conditions, such as 'rain' (falling drops) or 'fog'; others are more basic to the world and less obviously describable, such as 'light' and 'sound'. The latter actually play a part in determining the attributes of physical objects (e.g. light determines color). All members of this category, being neither mere objects, attributes or ACTs, seem to play an independent role in the world. In fact, many of the members of this category are those which are often thought by young children to possess animate qualities (5).

It is important to recognize such "active states" in completeing conceptual diagrams. For example, if the noun 'love' should be represented conceptually

as one <===> love (3), then 'sunshine' should be analyzed as sun <===> shine; we will not look for any external actor or action, since this noun accounts for both. We note that when such concepts are used as syntactic direct objects of a sentence, the verb has no meaning other than to assign an attribute or state to the syntactic subject. For instance, the sentence 'stoves radiate heat' means that stoves have the attribute of being 'hot'; 'candles give light' means candles 'shine' as an act-state. (There is a corresponding observation in the case of BASICs: to 'occupy space' is to exist spatially in a certain way; to 'pass time' is to exist temporally in a certain way. The verbs 'occupy' and 'pass' contribute no meaning in themselves.)

The conceptual dependence of a particular type of PA on a PHEN which is a medium through which a PP is perceived can be of use in the analysis of certain adjective-noun combinations which conceal conceptual information: Thus if we know that 'sharp' is in one sense a PA dependent (at least indirectly) on the PHEN 'sound' and a 'violin' is an instrument of making 'sound', then we can recognize that a 'sharp violin' is really a violin which, under a certain operation, emits a sharp sound, or a sound with a sharp pitch.

The fourth category (ATTRIB) consists of concepts which are physical properties or attributes, subcategorized according to whether they are QUANTs, QUALs or SPECs. QUANTitative concepts, which are nominalizations of inherent attributes, form a conceptually distinct PP-category in that they "map into" PAs in conceptual diagrams. For example, 'width', which expresses magnitude and is therefore a QUANT, has the PA-values 'wide' and 'narrow'. 'The width of the river is great' will conceptually be represented identically to 'The river is wide'. 'Color' is an example of a QUAL; it has qualitative rather than quantitative PA-values ('red', 'orange', etc.).

The third subcategory of ATTRIBs consists of SPECification attributes. SPECs also form a conceptually distinct PP-category; however, they map not into PAs, but into a conceptual notation intended to represent relations between PPs. In this sense they are not true, i.e. inherent attributes; they are "attributes" which by definition make reference to another PP. The relatively few items in this category include 'location', which is a point in the BASIC 'space', '$time_2$', which is a point in the BASIC '$time_1$', and 'distance' or 'proximity'. 'Distance' is easily seen as involving another PP. 'The distance (as an attribute) of A from B is great, small, 15 miles 'maps into $A \overset{(PROX\ .\ x)}{\Longleftrightarrow} B$, where x = 'great', 'small', '15 miles' respectively. (See Sections 3.3.1.1 and 5.3.) Here B may be a member of a special (BASIC-related) category called LOCATION, e.g. 'equator', rather than an ENTITY with physical properties. A similar situation holds for the lexical item 'location', which represents "zero distance" ($A \overset{AT}{\Longleftrightarrow} B$: See Sections 3.3.1.2 and 5.3.). In both cases there is an analogy with respect to time, though we are not concerning ourselves with the conceptual notation for temporal concepts here.

The fifth category ($ATTRIB_{+ANIM}$) is similar to the fourth, except that it consists of <u>animate</u> attributes, e.g. 'wisdom'. However, both categories of ATTRIBs are what we consider <u>abstract</u> nominals; they do not exist independently of some other (concrete) nominal. At this point we identify only one subcategory (TRAIT) of $ATTRIB_{+ANIM}$, while allowing that there may be others, depending on the useful distinctions found to exist between various types of animate ATTRIBs.

In classifying the existing different types of PAs by means of these last two categories, we note that nominalizations of adjectives such as 'pleasant', 'important' are not represented in our model. The reason is that such adjectives

represent <u>subjective</u> attributes; they should be 'rewritten' into conceptual representations which reflect the fact that it is the observer who in his attitude or feelings assigns such attributes to the object. For instance, 'Clear streams are pleasant' means essentially 'I like clear streams'; 'clear streams are important' means someone or a situation 'needs' clear streams, where 'need' can be expressed in primitive terms of 'want', 'have', 'purpose', etc. (6). Similarly, we exclude 'same' and 'taller' from this scheme on the basis that they are not true attributes of a single object but are rather <u>comparative relations</u> between two objects, i.e. a kind of logical primitive which relates any two objects.

We must also realize that the concept of number does not enter into our consideration of attributes. When we speak of the attributes of an object, we are referring to components of a representative image of this object. When we refer to e.g. 'three telephones', we are predicating three particular instances of sufficiently described telephones; the 'three' is not an attribute of the telephone but rather a specification made at a different level than that of dependencies.

Ordinals also need not be considered in identification of PP-PA dependencies. For instance, consider the pairs of sentences a) There were many wines on the table. The third from the left was the best. b) I tasted many wines last night. The third I tasted was the best. In neither case does 'third' apply directly to 'wine' conceptually. In the first case it applies to a spatial sequence; in the second to a temporal sequence. It may also apply to a sequence to which some other abstract category is relevant, such as "worth" ('the third best wine in California'). Thus ordinals apply to a PA dependent on a PP, rather than to the PP itself.

There is one more basic category to be considered, which bears some relation to ATTRIBs in that its members normally do not have an independent existence.

However, these PPs differ from ATTRIBs in that they are physical PARTs rather than mere descriptive aspects of objects. For an indication of the significance of PART as a category, see Sections 3.3.1.3 and 3.3.2.1.

3.2.3. Objects

The third group of categories consists of the "shaped" objects which result from application of elements of group two to those of group one. If MATTER (with associated ATTRIBs) is involved, we have a discrete "thing" or ENTITY. If ACTION is involved, we have a discrete time-object or EVENT. ENTITYs, of course, represent a vast number of different objects, and will be subdivided into one more level of categories in Section 4.1. Since the essence of an EVENT (as well as of an ACTION) is an ACT, (a 'game' is 'played') EVENTs can have temporal PAs ('long'--in time) associated with them. Since they have physical components, they may have certain spatial properties (location).

All of the categories identified above are conceptually basic enough so that members of any given category can all be expected to share the same basic or primitive dependencies on them. For instance, QUANTs all have 'amount', i.e. can be qualified by the PA 'great'. 'Amount' can in turn change in magnitude or increase as an ACT. There is little or nothing else that QUANTs can do, since they are abstract concepts. Syntactic predicates associated with them have no conceptual basis; i.e. in 'the width of the river impressed me', the presumed ACT 'impressed' takes place in the mind of the observer; it is not an ACT of the river or of the width.

A kind of matrix can be set up with the major categories to the left and the conceptual dependencies (PA-, ACT- and the various PP-dependencies to be identified below) on top. For each category, then, we can enter the corresponding primitive PAs and ACTs, or, for the PP-dependencies, major categories representing the "dependent" PP. Such a matrix, together with a brief discussion

of its contents and use, is relegated to the appendix, since it serves mainly as an overview of semantic dependency relationships, and involves some information which is yet to be introduced.

3.3. Static Relations

Subclassification of ENTITYs by dependency criteria is a more complicated problem than the analysis of other major categories. One reason, as far as our classification is concerned, involves the relations possible between concepts. Abstract concepts in general do not relate to other concepts except in the case of the association of the attribute with a concrete object ('the shape of the candle') and in the case of comparison of the degrees of an attribute ('the color of this block is more intense than the color of that one'). ENTITYs, which are concrete concepts, do relate to other concrete concepts. Furthermore, these concepts in turn may have parts or properties which may be related to making the possible types of dependencies, or "qualifying relations", potentially quite numerous and complicated.

When assigning categories or semantic descriptions to an ENTITY, we must keep in mind that this description will be relied upon by the semantic component in its work of deciding whether a certain dependency involving two nominals is allowable. We will therefore briefly examine basic static dependencies possible between two nominals and try to determine what features and categories they suggest which are critical to semantic descriptions of nominals. Any dependency, feature or category found to be relevant will be referred to in capital letters.

In the following section we will keep in mind not only the subclassification of ENTITYs but also any potential relations between the other basic categories we have established, except for ATTRIBs and ACTIONs, which are nominalizations rather than true conceptual nominals, and will use the term "PP" as referring

to such a conceptual nominal. Intuitively, a static relation or dependency between two PPs expresses either a spatial (locative) dependency or a dominance dependency.

3.3.1. Spatial or Locative Dependencies

3.3.1.1. PROXIMITY

One locative dependency is the PROXIMITY of one PP to another, or alternatively, the DISTANCE of one PP from another. The semantic restrictions on the PPs involved in such a dependency are conceptually only that they both have the property PHYSICAL, i.e. can have spatial coordinates. We want to accept 'the table near the tree', but not 'the idea near the tree'. One might observe that relative SIZE is also at least a probability criterion, i.e. there is something unusual about the PROXIMITY of a large object to a small one. However, SIZE restrictions are not really sufficient in determining the probability of PROXIMITY. There does not seem to be anything deviant about speaking of 'the mountain peak closest to the spring', since the spring might have some special importance as a location. It seems necessary and perhaps even more useful to acknowledge (in addition to SIZE) the distinction between objects which are normally ATTACHED to a surface, and objects which are free or not ATTACHED. Non-ATTACHED objects are less likely to be used as locative points of reference. We choose ATTACHED rather than DETACHED or FREE as the marked feature since attachedness implies more possible information as to how or where the object is attached; it is easier to have a corresponding positive value of a feature point to further information than a negative one in a program.

3.3.1.2. ATNESS

If we consider "zero distance" or "infinite proximity", we are dealing with the concept of ATNESS or IDENTITY. However, conceptual ATNESS does not merely express the extreme closeness of two objects. It rather expresses the idea of identity, between concepts which have a physical and perhaps a temporal component. If one is at a convention ('convention' being an EVENT, which therefore has both physical and temporal components), then we mean one is participating in the convention. If one is simply 'near a convention', his location is merely being specified. In general, it seems that ANIMATE beings, EVENTs and PHENs can be AT something which is PHYSICAL, ATTACHED and probably has a SIZE not significantly smaller than that of the ANIMATE being itself. In addition, ANIMATE beings and PHENs can be at EVENTs. (EVENTs are not AT EVENTs, since it is not the physical but rather the temporal components which determine the dependency here. Thus we would speak of "duration" rather than ATness, which lead out of our subject area into the analysis of whole conceptualizations.)

We do not conceive of inanimate objects being AT other objects since this would imply some sort of identity of position, mixing, or participation. (We can, however, envision any object AT a LOCATION, e.g. 'the trees at 6,000 feet', 'at the equator', etc. as mentioned in relation to SPECs in Section 3.2.2.) This interpretation of ATNESS helps us to distinguish conceptually between 'My pen is still at the meeting' and 'John is still at the meeting'. In the former example, the pen is located wherever the meeting is AT. In the latter, John is part of the meeting itself. The consequences for a parser in deciding on a conceptual representation for an input sentence, say, 'I dropped the book at the meeting', would be that 'at the meeting' would be chosen to be dependent on 'I' or on 'I dropped' (location of the event) rather than on 'book' (as if the book were a permanent part of the meeting).

3.3.1.3. POSITION

If PROXIMITY is conceivable for two PPs, or if one PP is as close as it can get to the other PP, i.e. is adjacent to it, then we can proceed to refer to the POSITION of one PP with respect to the other. In this case the parts of the second PP contribute to the specification of the location of the first. If the PPs are proximate to each other, we have e.g. 'the chair to the left of the desk'. If they are adjacent to each other, we have e.g. 'the picture on the desk, on the wall'. Most PHYSICAL ENTITYs can be considered to have parts, though these might not be geometrical parts, e.g. humans have noses. Thus from 'the fly on <u>his</u> <u>nose</u> (nose of him)' or 'on <u>top</u> of the <u>box</u>', we can know that 'nose' and 'top' are merely further specifications and that the 'fly' was really 'on <u>him</u>' or 'on the <u>box</u>'. We can also use this view of POSITION, (in this case adjacency or ONness) to explain why we tend to accept 'the fly on the ceiling', but not 'the ceiling on the fly'. A ceiling is (by definition: see Section 3.3.2.1) part of something. It is difficult for us to conceive of a "part" being on an object without the whole thing being on the object. As lexical items which map into conceptual POSITION-relations, we have not only 'at (to,on) the left of', 'over', 'behind', etc., but also 'beside', which expresses unspecified POSITION, 'on this (that) side of', which postulates a position <u>relative</u> to an assumed object or observer, and 'between' and 'among', which involve a plural PP.

3.3.1.4. ALONGNESS

In the types of location we have discussed so far, the independent PPs (as opposed to the dependent or qualifying PPs) were assumed to be points rather than dimensional objects. ALONGNESS is a dependency in which the dimension of both PPs is taken into consideration. A promenade is conceptually

ALONG a river only if it runs parallel to it. If it is in the same general area, but e.g. circular, it is merely beside the river. Thus ALONGNESS imposes a 1-DIMENSIONAL feature on the dependent PP. The independent PP may be either 1-DIMENSIONAL or a plural PP (points in a line) as in 'trees along the river'. Thus, given 'He threw the stone along the river', we would reject 'stone along river' as a unit in favor of 'threw along', whereas 'He threw the stones along the river' does yield 'stones along river' as one of the potential units.

That which can 'be along' can also conceptually 'be around' or 'surround' with certain restrictions on the topological properties of the dependent PP. There are other, more complicated relations of adjacency, as suggested lexically by 'against', 'straddling', which we will not spend time discussing here.

3.3.1.5. CONTAINMENT

Another important dependency is CONTAINMENT as expressed in English by 'inside', 'containing', etc. This is not a relation of location in the sense that POSITION is. CONTAINMENT involves the concept of boundary, and does not depend on the viewpoint of the observer. We must distinguish between two concepts of containment which visually are similar, namely containment as a capability (possessed by 'shoe') and containment as a function (possessed by 'box'). If we then encounter 'empty shoe box', we can assume that 'empty', which semantically refers to something which normally contains things, is dependent on 'box' rather than on 'shoe', although 'empty shoe' would certainly be accepted in the absence of 'box'. (Actually, the representation of this phrase can be more easily determined through the recognition of 'shoe box' as functional "object-container" as will be indicated in Section 5.) In any case, we can represent the distinction in the different implications of "containment" by establishing that the <u>ability</u> to contain will be given by the CONTAIN feature

of the PP, whereas the function of containment will be given by the explicit indication of 'contain' as a function of the PP (see dictionary sample in Section 4.4, under 'car' and 'glass1').

Another use of the feature CONTAIN (or the function 'contain', which implies CONTAIN, although not conversely) can be observed by considering the sentence The old man's glasses were filled with sherry'. The parser, upon encountering the word 'glasses', would probably first choose the sense of 'spectacles', since these are described as alienable attributes of humans (see Section 3.3.2.3). However, upon encountering the word 'filled', it would check for the attributive dependency of 'filled' on 'glasses'. 'Filled' or its synonym 'full' would be listed as a PA relevant to any object with the CONTAIN feature. The parser would then have to reject the original sense of 'glasses' for the sense of plural beverage containers.

The concept of containment or the ability to be "inside" is also strongly depndent on the feature ATTACHED as introduced in Section 3.3.1.1. This fact points to the obvious problem involved in insisting that a feature such as ATTACHED have either a strictly positive or strictly negative value. Plants, which are naturally ATTACHED, may be and often are detached, so that we would certainly want to accept 'the flowers in the box'. We would do this by prescribing in our system (Section 5.3) that anything can be contained which (in addition to SIZE requirements) has the possibility of being not ATTACHED, i.e. of being both ATTACHED and not ATTACHED. This possibility represents a third value with respect to this and possibly other features; namely that of variability between absolute positive and negative values.

3.3.2. Dominance Dependencies

Dominance is a basic PP-PP association in which one PP is semantically

subordinate to the other. Depending on which PP we are focusing on, we speak of possession, e.g. 'the x of y, y's x' and association, e.g. 'the y with (having) x'. As conceptually different instances of dominance dependencies we recognize inalienable part, alienable part, alienable possession and ownership.

3.3.2.1. Inalienable part (IPART)

Inalienable part dependencies are of significance in that whatever applies to the part, applies to the entity possessing it. (see examples in Section 3.3.1.3). As concerns semantic restrictions on the PPs involved, the IPART dependency can be allowed between x and y only if it is specifically known from the lexicon that x is a part of y. This is not too great a demand, since not too many parts can be inherent parts of many objects. These "parts" are recognized by their assignment to the major category PART, introduced in Section 3.2.2. This information from the dictionary contributes to a reasonable analysis of the sentence 'John hit the boy with long hair': 'Hair' as a PART of a HUMAN or ANIMAL would not normally be considered an instrument of hitting; thus the IPART dependency between 'boy' and 'hair' is preferred to the choice of 'hair' as an instrument. It might be pointed out the IPART dependencies (as well as certain other dependencies) actually involve hierarchies, e.g. a stem is a part of a plant, which is part of a garden ..land...world... However, it is only the immediate IPART dependency which is meaningful. We want to accept 'stem of plant' but not 'stem of garden'.

(Note: ATTRIBs as inalienable aspects of objects also represent IPART dependencies, as referred to in the appendix. In this case, the IPART dependency is abstract, as can be distinguished by recognizing the abstract character of the ATTRIB.)

3.3.2.2. Alienable part (APART)

Alienable parts are more difficult to determine, since they can combine with objects in different ways. It is required at least that both possessor and possessed by a MAN-MADE ENTITY. However, in order to satisfactorily exploit the identification of an APART dependency, the dictionary should be able to tell us of some specific <u>functional</u> relationship of the part to the possessor. (See notes in Figure 3-1 under PART-AL.)

3.3.2.3. Alienable possession (APOSS)

A possessor of an alienable object must be a HUMAN or ANIMAL, since he does not automatically occur with the possessed object and must consciously associate himself with it. The object must be PHYSICAL (or as a special case, be $space_1$ or $time_1$). In addition, since the dependency is one of physical domination, the object must be capable of being not ATTACHED and must fulfill certain rough SIZE requirements. Thus we can know that 'the girl with the doll' and 'the doll with the girl' both involve a situation in which the <u>doll</u> is an alienable possession of the <u>girl</u>. In parsing 'He left his dog in the field with the girl', we would reject 'field with the girl' as a unit, since 'field' can not be "not ATTACHED" to be physically possessed by the girl, or alternatively, since a non-HUMAN object cannot possess a HUMAN being.

3.3.2.4. Ownership (OPOSS)

Ownership relies on a social agreement; therefore only HUMANs, INSTITUTIONs and possibly ANIMALs can possess in this way. (Here we mean INSTITUTION in the sense of the physical entity in which humans are involved, rather than some abstract phenomenon instituted by man.) Anything PHYSICAL, including MATTER,

can be owned. In addition, the objects of social agreement themselves, which according to HUMANs indirectly represent physical PPs (such as 'money', stocks') can of course be owned. Distinguishing social possession (OPOSS) from physical possession (APOSS), though the two sometimes coincide, has obvious consequences for the conceptual analysis of a situation and the resulting inferences which one can make.

4. Specification and Implementation of Category System

4.1 Explicit and Implicit Category Definition

The criteria which have manifested themselves in the preceding discussion, as well as others, combine in various ways to determine semantic categories of PPs, particularly of ENTITYs. If, however, we established a category for each such combination of semantic features, the precise implications of the category names (of which there would be 2^n, where n is the number of features) would cease to be obvious to the person defining words semantically in the dictionary or programming the semantic tests. Furthermore, a sole reliance on explicit categories would mean, as suggested in Section 2.3, that a number of categories would have to be listed for cases in which the specification of a single semantic feature common to all these categories would suffice to indicate the semantic criteria under consideration.

We therefore find it convenient and necessary to introduce a feature system to further specify the semantic description of ENTITYs and perhaps of other major categories, such as MATTER. It would be a system in which a given concept has a positive (+), negative (-) or in some cases a variable (±) value for each feature relevant to it. The following features have initially been identified as relevant to dependency considerations, on the basis of the observations of Section 3.3 and as exemplified in Figure 3:

± PHYSICAL	(PHYS)
± MENTAL	(MENT)
± CONTAIN	(CONT)
± 1-DIMENSIONAL	(1D)
± ATTACHED	(ATT)
± COMPLEX	(COMPLEX)
± MAN-MADE	(MM)

± ANIMATE (ANIM)

± ENVIRONMENT (ENVMT)

± FLUID (FLUID)

Some of these may be interdependent, e.g. +ANIMATE implies +MENTAL (but not conversely: 'book' has the +MENTAL but not the +ANIMATE feature).

The feature ±COMPLEX is perhaps not immediately obvious, and has not evolved from our discussion of dependencies between PPs. Rather it concerns dependencies involving the concepts of being "created" or "destroyed", which represent a pair of basic ACTs which must be recognized in a complete semantic category system (6). For example, any concept which has the feature +PHYS, +COMPLEX can be 'built', 'repaired', etc.

It is apparent that certain configurations of these features occur frequently and recognizably. There is no need to rely exclusively on a feature description if an explicit category is universally recognizable. Such minor categories will always imply a specific permanent feature configuration in which some of the features have fixed values and others are variable. The alternatives offered by this mixed category- and feature-method of description provides flexibility for the person entering information into the dictionary or the semantic component. Minor categories and their "built-in" feature configurations are given in Figure 1.

A comprehensive or high-level feature may be equivalent to or expressed as a minor category itself. For example, instead of (or in addition to) a category HUMAN, we might have the feature +HUMAN, which applies to humans and the category INSTITUTION (of which humans are a part). We have not at this stage placed too much importance on the choice involved in these alternatives.

4.2. Functional Criteria and Specification

Before explaining how the semantics programs and the dictionary interact to

give information on dependencies, we need to consider how knowledge of the functional properties of a PP can aid in constructing a "correct" conceptual diagram on the basis of inadequate lexical input.

4.2.1. Instrumentality

Most man-made objects have only one specific function--the function for which they were created--associated with them, although they may in fact be capable of "doing" a few other things. (In the dictionary descriptions this information is given under FUNCTION or FN). In addition, specialized parts of animate beings, e.g. the sense organs, are recognized to have a function. "Functional" PPs of both of these types are often thought of as instruments. In English this is usually realized by the preposition 'with'. They differ somewhat in that the instrumentality of the animate-part PPs is usually redundant, since such PPs are internal to the being performing the action, and are part of the definition of the action itself. However, in both cases, if we include the instrumental function (INSTR) of the PP in the semantic description of the PP, we can use this information to reconstruct "missing" concepts during operation of the semantic component. Thus 'He used chopsticks' can be understood to imply that he <u>ate</u> with chopsticks. 'He has good eyes' means 'He sees well'.

4.2.2. Direct Use

Some man-made objects are thought of not as being incidental or subordinate to actions of the user, but rather as being appreciated directly. Thus cigars are smoked, books are (in the absence of other information) read. If we include such information in the dictionary (under USE), we can guess that 'I like books' is equivalent to 'I like reading books', and include the concept of 'read' in the conceptual diagram.

If the "object" of a verb is not a man-made or functional object, such

<u>MINOR</u> <u>CATEGORIES</u> (SUBCATEGORIES of "ENTITY")

with "built-in" feature values

CATEGORIES

FEATURES	<u>HUMAN</u>	<u>INST</u>ITUTION	<u>ANIM</u>AL	<u>PLANT</u>	<u>ENV</u>IRONMENT	<u>INFO</u>RMATION	<u>M</u>ENTAL <u>OBJ</u>ECT	<u>P</u>HYSICAL <u>OBJ</u>ECT
PHYS	+	+	+	+	+	+	-	-
MENT	+	+	+	-	-	+	+	-
MM	-	+	-	-	±	+	-	±
ATT	+	-	+	±	-	+	+	±
CONT	-	±	-	-	+	±	±	±
1D	-	-	±	±	±	-	-	±
COMPLEX	-	+	-	-	±	±	±	±
ENVMT	-	±	-	-	+	-	-	-
ANIM	+	+	+	-	-	-	-	-
FLUID	-	-	-	-	±	-	-	± *

FEATURES which apply to MATTER: ± <u>MAN</u>-<u>MADE</u>
± FLUID

*e.g. 'cocktail'

Figure 1

information will not help us. However, we can guess that in such a case, the missing ACT is some form of observation--participation or presence for EVENTs ('Harry prefers football games), and mutual presence for natural or non-man-made objects ('High cliffs scare me', 'I like flowers, find flowers pleasant, etc.').

4.3. Construction of Semantic Descriptions for the Dictionary

Entry of semantic descriptions of words into the dictionary should be such that the person(s) responsible for this task does not have to decide for each item what type of information is relevant. He should only have to fill in built-in "slots". The semantic category system we have described is suitable to fulfill such requirements and has been implemented as an interactive dictionary editor together with semantic programs (to be described in Section 5) on an experimental basis on the Stanford Artificial Intelligence Project's PDP-6/10 time-shared system. The programs were written in MLISP (10).

The operation of the editor depends mainly on questions and prompts for information. For each PP, the program offers the user, or monitor, the list of major categories and asks for a choice. The selection determines possible further questions. The category generally requiring the most detailed information is ENTITY. In the case of ENTITY the program asks for selection of one of the minor categories identified in Figure 1. (It is conceivable that a PP might fit into more than one of these, depending on how they are defined, although in this implementation such confusion has so far been avoided by assigning priorities to the minor categories.)

Once the explicit category of the PP is established, the program proceeds to ask for values for those semantic features of the item which are relevant to the category but unspecified as to value. Given a certain feature value, the program may prompt the user for one further level of relevant information. The program then constructs the semantic description of the PP on the basis of the

information it has received.

The "further level of relevant information" mentioned above is solicited as follows. Since the major category EVENT includes some sort of action as part of its definition, the program asks for the ACT which is associated with the given nominal. For instance, for 'game' this would be 'play'. The semantic description is then simply (game EVENT play). (We will ignore the subscripts necessary to distinguish senses in this discussion, unless more than one sense actually occurs in our examples.) 'Baseball' in the sense of a type of game activity is described as an ACTION which also has associated with it the ACT 'play'.

A similar situation holds for the PHEN category; e.g. (light PHEN shine), where 'shine' is the associated "ACT-state". If the PP is a PART, the categories and names of the possessing entities are asked for, as in (arm PART CATEGORIES: (HUMAN) SPECIFIC: (chair robot)). In the case of ATTRIBs, the program asks for "high" and "low" values of QUANTs (for 'width' this would be 'wide', row'), and for a list of values of QUALs (for 'color' this would be 'red', 'nar- 'orange', etc.). Presumably all SPECs could be included in the dictionary from the beginning; however, if any are added, the procedure would be similar to that of other ATTRIBs. LOCATION evokes a prompt for a possible 1-DIMENSIONAL property. In order to handle the special case of proper names, the possibility of the pseudo-major-category NAME has been included. In this case the editor simply enters the item (e.g. 'California') as an INSTANCEOF whatever concept the monitor gives upon prompting ('state').

If a PP is of the major category ENTITY, its semantic category appears in the dictionary as its minor category (the program notes the "mini-hierarchy" represented by the one-level subcategorization of ENTITY). The most significant feature is probably the MAN-MADE (MM) one, from which further information about the utility of the PP is derived. In the semantic description this information

appears in the form of the FUNCTION (FN), direct or appreciated USE, INSTRumental use and specific ACTs of the PP. An INF, which is a +MM physical expression of communication, has in addition to USE a form of creation (CREATE). The ACT under 'FN' is the purpose of the PP, if a unique one is recognized. (It should be noted from the examples we shall use that the "ACTs" are often verbs, that are "rewritten" into more primitive concepts in the verb-ACT dictionary (8).) Any ACT(s) under 'ACTS' are ACT-associations due to the nature of the PP, but do not represent the complete purpose of the PP. For instance, a 'school' has as its function to 'teach' (with all that is implied by that), but has no other ACTs besides those which all INSTITUTIONs are capable of. A 'ball' has no FN, or rather its function is represented implicitly by its INSTRumental function ('play'). However, it has the "rather ball-specific" ACTs 'bounce' and 'roll'. A 'knife' has both as its FN and its INSTR function the ACT 'cut'. If the FN involves another PP or category as an "object", this PP or category is included in the information. In general, such category information in the dictionary can be given either by category name or by reference to features.

Some examples (omitting information not relevant to the illustration) are:

(factory INST ... MM (FN: (MAKE +MM) ...)
(school INST ... MM (FN: (TEACH MOBJ) INSTR: (LEARN MOBJ)) ...)
(cigar POBJ ... MM (USE: smoke ...) ...)
(book INF ... MM (USE: read CREATE: write) ...)

The PHYSical feature determines that SIZE considerations will be relevant. Size information becomes useful in the determination of the probability of 1) many specific physical relationships, 2) the involvement of an object in animate actions, which will not be considered in this paper. The size scale we adopt should not arbitrarily progress linearly, but should reflect differences which are pragmatically useful. A suggested scale (which must necessarily be

crude) is:

	0 = less than or equal to insect
	1 = able to be held in hand
SIZE	2 = about like human
	3 = habitable by human
	4 = greater than above

The relevant part of the format looks like: (ball POBJ ... PHYS(1) ...). Although the dictionary up until the present included size information only for the explicit category POBJ, it is probably necessary to do the same for all or most minor categories with the +PHYS feature.

The feature ±ENVMT, which is common to both the categories ENV and INST (a 'school' as a human INST is an example of a PP which has an environment feature but is not identical to the environment category) also implies further information. This consists of the categories or specific names of the possible permanent but not inalienable contents of the environmental aspect of the PP, and the next largest environmental container of the PP. For example: (park ENV ... ENVMT (CATEGORIES: (PLANT ANIMAL) SPECIFIC: (statue ...) CONTR: city) ...).

4.4. Dictionary

A sample part of the dictionary appears in Figure 2. Starred items are discussed briefly, following the sample, with respect to problems which have been noted. The presence of a feature name means a positive value for that feature. A '-v' appended to the feature implies the value of the feature is variable. Some ENTITYs are obviously ATTached, but the feature is not given explicitly, since the minor category (INST, ENV) implies ATTachedness. The necessary additional information relevant to ATT or ATT-v has not yet been implemented and does not appear in this sample.

DICTIONARY SAMPLE

(arm PART CATEGORIES: (HUMAN ANIMAL) SPECIFIC: (chair robot))

(baby HUMAN)

(baseball1 POBJ PHYS (1) MM (INSTR: play ACTS: (bounce roll)))

(baseball2 ACTION play)

(bird ANIMAL PHYS (1))

* (book INF PHYS (1) MM (USE: read CREATE: write) CONT)

* (button1 POBJ PHYS (0) MM (INSTR: button2) ATT-v)

(California INSTANCEOF state)

* (car POBJ PHYS (3) CONT 1D-v MM (FN: go USE: drive INSTR: (go) ACTS: (run)) COMPLEX) (chair POBJ PHYS (2) CONT MM (INSTR: sit))

(chocolate MATTER MM (USE: eat) FLUID-v)

(cigar POBJ PHYS (1) MM (USE: smoke) 1D)

(city INST MM (FN: govern) ENVMT (CATEGORIES: (+PHYS PHEN EVENT) CONTR: state))

(cocktail POBJ PHYS (1) MM (USE: drink) FLUID)

(color ATTRIB QUAL (red ...))

(computer POBJ PHYS (2) MM (FN: compute INSTR: compute) CONT ATT-v)

(factory INST MM (FN: (make +MM)))

(flower PLANT PHYS (1) ATT-v)

* (forest ENV ENVMT (CATEGORIES: (PLANT ANIMAL) CONTR: city) COMPLEX)

(game EVENT play)

* (glass1 POBJ PHYS (1) MM (FN: contain) CONT)

(glass2 MATTER MM ( ))

(idea MOBJ)

(knife POBJ PHYS (1) MM (INSTR: (cut stab) FN: (cut)) 1D)

(lake ENV ENVMT (CATEGORIES: (ANIMAL PLANT) CONTR: city))

(light PHEN shine)

(linguistics MOBJ COMPLEX)

(movie INF MM (USE: watch CREATE: film))

(park ENV ENVMT (CATEGORIES: (PLANT ANIMAL) SPECIFIC: (statue bench)
    CONTR: city) COMPLEX)

* (police INST MM (FN: (enforce law)))

(pool ENV ENVMT (CATEGORIES: (ANIMAL) CONTR: city))

* (room ENV ENVMT (SPECIFIC: furniture CONTR: building))

(rubber MATTER)

* (school INST MM (FN: (teach MOBJ) USE: (learn MOBJ)) ENVMT (CONTR: city)
    COMPLEX)

(San-Francisco INSTANCEOF city)

(soup MATTER FLUID MM (USE: eat))

(spoon POBJ PHYS (1) MM (INSTR: eat))

(state INST MM (FN. govern) ENVMT (CATEGORIES: (ENTITY EVENT PHEN)
    CONTRA: country) COMPLEX)

(train POBJ PHYS (3) MM (FN: go INSTR: go ACTS: (run)) CONT 1D COMPLEX)

(tv POBJ PHYS (2) MM (USE: watch) COMPLEX ATT-v)

(wine MATTER FLUID MM (USE: drink))

Comments:

book

±CONT refers to physical containment. We are for the moment assuming that mental containment follows automatically from a +MENT feature, but this remains to be more carefully considered and tested. In any case, we wish to be able to specify two distinct interpretations of the sentence 'There is a four-leaf-clover in this book', one at the physical and one at the mental level. (See also Celce and Schwarz (3).)

button]

See Figure 3- for a note on the problems involved in the semantic description of this item.

car

'Car' is described here as having the functional ACT 'go' and the more general ACT 'run'. The original motivation for including 'run' here was that 'run' did not take up any more room than an explicit superset-category 'machine', which can 'run'. This question is not too important for resolving PP-PP ambiguities, in which we are chiefly interested. 'Go' provides all the information we need. However, we might in other cases wish to know that a car is a machine. For example, 'I have to take my car in. The old machine isn't running too well'. Thus it would be useful to indicate that a 'car' is a member of the special superset category 'machine', and eliminate 'run' as an ACT for 'car'. This would imply that the functional ACT and USE of 'machine' ('run' or 'work' 'operate') apply also to 'a car'.

We stated earlier that we did not wish to deal with lower-level categories, since the more categories there are, the less easily they will be able to be referenced. However, in consideration of the above advantage plus that given under 'room', it seems expedient to be able to create such special categories in this restricted context as the need occurs.

forest

Although forests are not usually thought of as being in cities, the criterion here is the ability to contain. The CONTR: mechanism is actually oversimplified at this state: The containing concepts are hierarchical, i.e. strictly ordered in one chain, e.g. a forest is in a city, which is in a state... country.... A more reliable structure would be a directed graph, in which forests and cities could contain each other, and a forest could be contained by at least two parallel environmental concepts--one a city (INST), the other a SIZE-determined group of ENVs which includes 'valley', 'mountain', etc.

glass1

Although most FNs are conceptual ACTs, 'contain' is not really an ACT, and will not be represented as such in the conceptual diagram. However, it is the only way we can represent the FN from the point of view of the 'glass'.

police

This is an example in which a compound concept ('enforce law') represents a complicated conceptual structure. To pick up and use this conceptual structure is one of the more difficult problems. However, it should be remembered that the ability to do this consistently implies quite a powerful and refined semantics component. If we know only the fact that the police are a human INSTitution with a function, we have enough information to avoid semantic disasters.

room

Here we have another use for special categories, as indicated in the comments for 'car'. We obviously do not wish to be obliged to list all the different types of buildings which can contain rooms, or types of furniture which can be contained in rooms. One solution for such a case would be to have a special notation for a concept such as 'building', which has the characteristic of a category, at least in some cultures. This notation would imply a substitution of the members of the category for this concept, whenever it is used to fill in a slot, as in

the example we are considering. The semantic component, however, would never explicitly reference any one of these ad-hoc categories, since it should be more or less language-and culture-independent.

<u>school</u>

Here the object of 'teach' (MOBJ) is not quite adequate to express all that can be taught. The concept of teaching ideas or bodies of knowledge is captured, but not the concept of teaching how something is done. This problem results because 'MOBJ" is an oversimplification of a complex conceptual structure.

The questions relevant to such semantic descriptions will be more fully appreciated in considering some of their applications (Section [illegible]. In any case, it does not appear that there are any theoretical barriers to correcting the weaknesses which have presented themselves.

5. Interpretation of Nominal Pairs

As an example of the value of the relatively small amount of information constituted by the semantic descriptions in the system we have described, we will show how a dictionary comprised of such descriptions can be utilized for determining the meaning of noun-pairs, as mentioned in Section 2.1. Su (11) has recognized the problem of the "interactive meaning", as he calls it, of such noun-pairs and has been able to identify and paraphrase a fairly large number of them. We have a somewhat different way of classifying the types of interactive meanings which exist, as we are striving for consistency with an established conceptual dependency system and are interested in the "primitive" relationships which manifest themselves among these noun-noun dependencies. Furthermore, we are encoding interactive meanings on the basis of the category system we have described, rather than on the basis of a purely hierarchical system.

5.1. Nature of the Dependency

There are basically two types of links which may exist between the nouns in question. We can refer to them as "simple" and "complex". A simple link itself consists of two kinds. The first kind is a basic static link corresponding to some of the PP-PP dependencies discussed above, as well as others. English noun-pairs involving this type of link are lexically related to PP-PP dependencies: The noun-pair PP_1 PP_2 often has the prepositional-phrase counterpart PP_2 PREPOSITION PP_1, e.g. 'field bird', 'bird in field'. The second kind of simple link is analogous to the first except that non-static (but still primitive) links such as SOURCE and GOAL are involved. These noun-pairs are thus related to conceptualizations in which one of the PPs in the pair is in the Recipient or Directive case (Schank (8)). For instance, a 'moon rock' corresponds to a 'rock from the moon'.

In the complex links, the first noun is either a conceptual ACT or the object of an implicit ACT relating the two concepts, e.g. 'swimming pool' and 'bread knife' respectively. Representations of such forms will be more complicated than those involving simple links. In the conceptual representation of both types of noun-pairs, the notion of habit or of function is present.

5.2. Criteria for Choosing Correct Representation

The choice of conceptual representation of a noun-pair depends on the semantic category of each word and the most likely dependency between these two categories. The tests as to whether a given noun-pair fits a certain semantic pattern must be made in a predetermined sequence in order to establish priorities in the case of more than one conceivable interpretation. The fact that order is relied upon reflects the use of certain global heuristics which humans use when choosing an interpretation. For example, although we can imagine a factory made out of glass (where the sense of 'glass' is that of the material), we would prefer to interpret a 'glass factory' as a factory which makes things out of glass, since 'factory' is a much more specific concept than "physical object"; a qualifier associated with 'factory' would be expected primarily to relate to the special functions of 'factory'. Our implementation returns the following ordered list of representations (the English counterpart of the actual conceptual representation output is given here):

factory which makes objects out of glass

factory which makes glass

factory made out of glass

The program which implements interpretation of noun-pairs of both types mentioned is basically simple, since our "model of the world" has already pre-

determined which information about nouns is relevant in deciding dependencies between them. Since we are mainly concerned with knowing whether a dependency is conceivable rather than whether it is a "usual" association in our experience, the amount of information to be accessed is relatively small. (Further research will no doubt indicate that more information is necessary for intelligent dependency judgments; however, the amount should be of the same order of magnitude.) The work of the program essentially consists of 1) running through the ordered functions which test whether the given noun-pair satisfies the contextual requirement for a dependency in terms of the nouns involved and 2) returning the ordered list of dependencies resulting from positive tests. The semantic definitions are obtained from the dictionary described in Sections 4.3 and 4.4. The tests consist of functions applied to the given nouns and their semantic descriptions. It is expected that the second noun will be of one of the major nominal categories we have considered, and that the first noun will be of such a category or it will be a conceptual ACT.

The program also allows for a special kind of noun-pair, namely one in which the first noun is a proper name, i.e. an instance of some concept as recognized from the semantic description of the noun (Section 4.3). In such a case the concept with which the name is associated is recognized, but not <u>necessarily</u> considered equivalent to the name, as far as the effect on the dependency is concerned. For instance, the somewhat subtle difference in dependency between 'California baseball' and 'state baseball' is recognized by the program. 'California baseball' refers to baseball played in (the environment of) California, whereas 'state baseball' refers to baseball which is run by the (institution) state.

Example of nominal-pair solutions according to tentatively identified tests are given in Figure 3. In general, only one representation is given for each example, whereas the program also returns any "less likely" representations

for consideration. The priority of the tests is given at the left, although it should be remembered that it reflects a sequence which established itself during the period of testing but can expect to be altered in the course of further development of the system.

5.3. "Prepositional" Dependencies

Much of the same information and methods used to resolve noun-pairs are also relevant to judging PP-PP dependencies, usually expressed in English by a noun qualified by a prepositional phrase. The latter problem involves considering e.g 'glass of wine' or 'wine in glass' rather than 'wine glass'. (In French a fairly regular correspondence occurs between lexical phrases, e.g. 'verre de vin', 'verre a vin', and conceptual notions of actual and functional links.) However, it is obvious that the problems are not identical. The association between two nouns must be more obvious for the nouns to function as a noun-pair unit, than to be related through an explicit relation (preposition). A program, minimally tested as to adequacy, has been written which judges such phrases with regard to the intended conceptual relation expressed by a syntactic preposition which potentially has multiple senses.

The program accepts as input a "prepositional phrase" of the form (PP_1 PREP PP_2), where PP_1 is the independent PP, PP_2 the qualifying PP and PREP the preposition considered by the parser as relating the two PPs. Output is either NIL or a conceptual representation(s) in the form

$$\begin{array}{c} PP_1 \\ \uparrow \\ PP_1 \overset{\langle RELN \rangle}{\Longleftrightarrow} PP_2 \end{array}$$

or the "reciprocal" representation

$$\begin{array}{c} PP_1 \\ \uparrow \\ PP_2 \overset{\langle RELN \rangle}{\Longleftrightarrow} PP_1 \end{array}$$

where RELN is a <u>conceptual</u> preposition or relation of the type discussed in Section 3.3. For example, an input

NOUN-PAIR REPRESENTATIONS

PRIORITY	FUNCTION NAME	EXAMPLE	SEMANTIC CRITERIA for NOUN 1 and NOUN 2	REPRESENTATION if CRITERIA SATISFIED
20	COMPOSITION	rubber knife	N1 = MATTER and -FLUID N2 = +PHYS and -ANIM	knife ↑ COMPOSITION rubber
19	EVENT_COMP	baseball game	N1 = ACTION (ACT = x) N2 = EVENT (ACT = x)	game ↑ (ACT-) COMPOSITION baseball
1	PART_INAL	chair arm	N1 = specific object or category of objects of which N2 is an inalienable part N2 = PART	arm ↑ arm <===> chair IPART
2	PART_INAL_RECIP	arm chair	N1 and N2 are exchanged, and PART_INAL holds	chair ↑ arm <===> chair IPART
13	PART_AL	coat button1	N1 = POBJ and +MM (USE: x) N2 = POBJ and +MM (INSTR: x) x = button2 here (This test is somewhat optimistic in expecting that the semantic descriptions will actually provide the exact information required! However, some specific association between N1 and N2 must be identifi[ed] since most (POBJ and +MM) -pairs must be rejected in the absence of other information (e.g. 'coat candle').)	button1 ↑ button1 <====> coat APART
14	PART_AL_RECIP	button coat	N1 and N2 are exchanged, and PART_AL holds	coat ↑ button1 <====> coat APART

Figure 3-1

10	POSSESS	baby book horse shoe	N1 = HUMAN or INST or ANIMAL (pet) N2 = +MM (USE: x) x = read, wear (As regards 'baby book', DESCRIPTION has higher priority than POSSESS)	book (shoe) ↑F c baby <====> read < book (horse) (wear) (shoe) (F = function as specified by the lower part of the conceptual diagram; c = "can", i.e. hypothetical action)
		baby cup	N1 = HUMAN or ANIMAL (pet) N2 = +MM (INSTR: x) x = drink Note: The preceding examples include the concept of APOSS, and the following example the concept of OPOSS. However, when a function is involved, as is often the case in noun-pairs, it is desirable to represent this function rather than the less informative A(O)Poss in the conceptual diagram.	cup ↑F c I baby <====> drink (F_I = "instrumental function", i.e. 'cup' is used in some unspecified way)
		company limousine	N1 = INST N2 = +MM (INSTR: x) x = go	limousine ↑F c I company <=====> go (i.e. human members)
9	CONTAIN	wine glass	N1 = MATTER or (POBJ and ±ATT) N2 = POBJ and +MM (FN: contain)	glass ↑F c wine <=====> glass IN

Figure 3-2

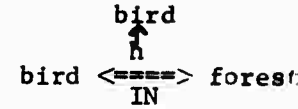
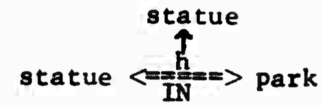
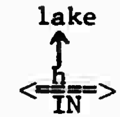
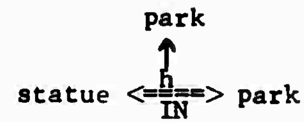
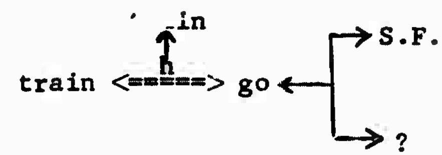
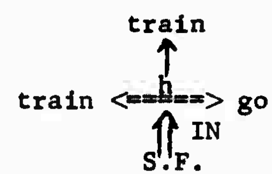
8	D_SOURCE	forest bird	N1 = +ENVMT N2 is contained in list of categories (i.e. ANIMAL) found in N1	 (h = habitual)
		park statue	N1 = +ENVMT N2 is contained in list of specific things found in N1	
		California lake	N1 = +ENVMT N2 = +ENVMT and is contained by something identical to or contained (recursively) by N1 (information from CONTR:)	
7	D_SOURCE_RECIP	statue park	N1 and N2 are exchanged, and D_SOURCE holds (Because proper names in the position of N2 are not recognized anywhere, 'lake California' will not even get to the tests)	
18	D_GOAL	San Francisco train	N1 = +ENVMT N2 = POBJ and +MM (FN: go)	 OR  (Does not at this level distinguish that trains usually go between (to) cities and trolley cars go within cities

Figure 3-3

6	R_SOURCE	factory glass	N1 and N2 are exchanged and R_SOURCE_RECIP holds	glass ↑ factory <=====> make <—— glass
5	R_SOURCE_RECIP	glass factory	N1 has category X or feature specification + (or $\pm$) Y N2 = INST (FN: (<FUNCTION>...X or ($\pm$) Y)) Here FUNCTION = make Y = (+)MM	factory ↑ F c factory <=====> make <—— glass
17	R_GOAL	kitchen table	N1 = ENV and +MM N2 = (not MATTER) and +MM	table ↑ F table <=====> kitchen IN
4	INSTPAIR	state police	N1 = INST and +ENVMT N2 = INST and -ENVMT	police ↑ h state <=====> employ<—— police ('Employ' is "built into" and is a complex verb" re-written" in the verb-ACT dictionary)
		police state	N1 = INST and -ENVMT N2 = INST	state ↑ h police <=====> run <—— state ('Run': cf. 'employ')
12	EVENT_OBJ	game park	N1 = EVENT (ACT = x) N2 = +ENVMT x = play	park ↑ F c one <=====> play ⇑ IN park
		game ball	N1 = EVENT (ACT = x) N2 = -ENVMT and +MM x = play	ball ↑ F I c one <=====> play

Figure 3-4

15	ACT_OBJ	swimming pool	N1 = ACT N2 = ENV (Could use somewhat narrower restrictions on N2)
		baseball park	N1 = ACTION (ACT = x) N2 = ENV x = play
11	ACT_COND	field hockey California baseball	N1 = +ENVMT and ((not INST) or variable TOKEN is TRUE i.e. N1 is proper name) N2 = ACTION
		state baseball	N1 = +ENVMT and INST and TOKEN is FALSE N2 = ACTION (ACT = x) x = play
3	DESCRIPTION	baby book	N1 = PP N2 = INF

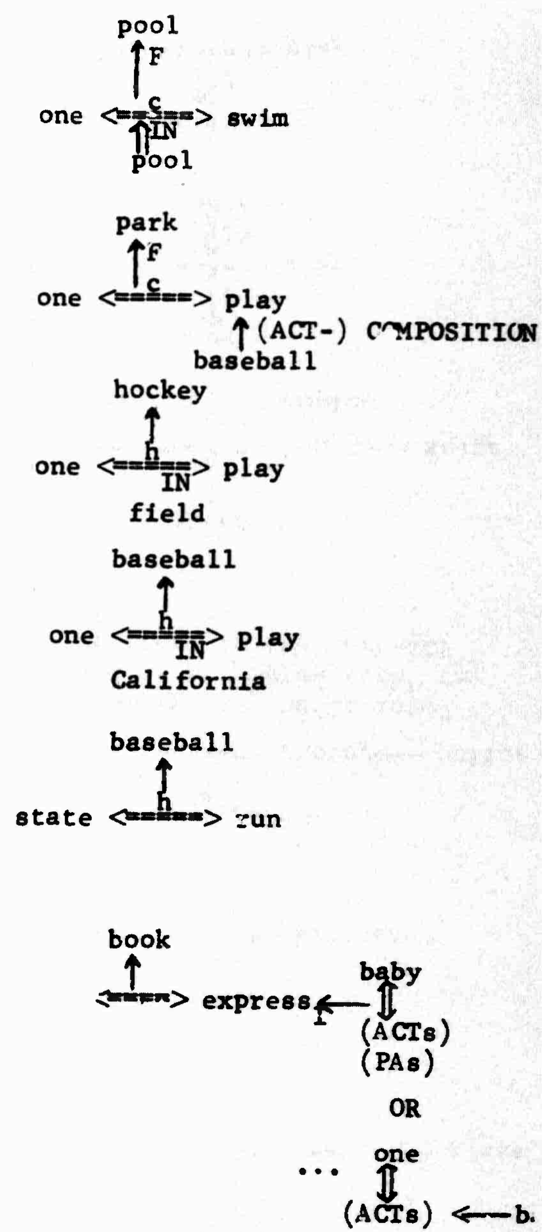


Figure 3-5

16	ACT_LINK	soup spoon	N1 = (MATTER or POBJ or INF) and +MM (USE: x) N2 = +MM (INSTR: x) x = eat	spoon ↑F I one <==c==> eat ←— soup
		tv room	N1 = as in preceding example N2 = +MM and ENV x = watch	room ↑F one <==c==> watch ←— tv ⇑IN room
21	ACT_UNKNOWN	flower knife	First condition, by virtue of lowest priority: all other tests fail N1 = ENTITY N2 = POBJ and +MM (INSTR: x) x = cut	knife ↑F one <==c==> cut? ←— flower ('?' indicates a guess)

Figure 3-6

of 'window of wine' gives NIL; 'lion inside house' gives $\begin{array}{c}\text{lion}\\ \uparrow\\ \text{lion} \overset{\text{IN}}{\Longleftrightarrow} \text{house}\end{array}$.

'Man with hair' gives $\begin{array}{c}\text{man}\\ \uparrow\\ \text{hair} \overset{\text{PART}}{\Longleftrightarrow} \text{man}\end{array}$ which involves a "reciprocal" PART-relation.

It considers $\begin{array}{c}\text{man}\\ \uparrow\\ \text{man} \overset{\text{APOSS}}{\Longleftrightarrow} \text{hair}\end{array}$ as in the sense of 'dog with 'girl', but rejects it, since a 'man' cannot be an alienable possession of 'hair'.

The program accepts not only phrases which potentially involve conceptual prepositions, but also those which contain syntactic prepositions which do not map into conceptual prepositions. For instance, 'x about y' may be recognized as a conceptual "rewrite" involving the ACT 'express' rather than a $\begin{array}{c}\text{x}\\ \uparrow\\ \text{x} \overset{\text{"about"}}{\Longleftrightarrow} \text{y}\end{array}$ representation (see example "DESCRIPTION", Figure 3-5, which reflects a similar situation for noun-pairs). "Logical prepositions", however, such as in 'everyone <u>except</u> me' are not handled by this program. Conceptual interpretations of syntactic prepositions, as well as the semantic conditions (on the involved PPs) which are used in deciding output representations, are given in Figure 4.

5.4. Evaluation and Discussion

Although the data base is at yet too small to allow any objective statistical assessments, it is apparent that the program can handle a sizeable majority of random combinations of nouns defined in the dictionary. More subtle discrimination criteria perhaps culturally based, will certainly be needed eventually. However, we assert again that we should resort to specific experience with caution. Although computers are not generally found in parks, for example, the program identifies a 'park computer' as a computer found in a park, which is entirely conceivable and may in fact not be unusual at some future time.

Aside from pragmatic considerations, this system contributes an opportunity

PREPOSITIONAL-PHRASE REPRESENTATIONS

CONCEPT and RELEVANT LEXICAL PREPOSITIONS	CONCEPTUAL RELATION	EXAMPLES	SEMANTIC CRITERIA for PP1 and PP2	REPRESENTATION if CRITERIA SATISFIED
Spatial Relations:				
ATNESS at	AT	bike at lake	PP1 = +PHYS PP2 = +ENVMT	bike ↑ bike <=AT=> lake
			or	
		woman at meeting	PP1 = HUMAN or ANIMAL PP2 = EVENT	woman ↑ woman <=AT=> meeting
CONTAINMENT in . . . . . inside (of) within	IN	wine in knapsack map in car	PP1 = +PHYS PP2 = +CONT and SIZE of PP1 not greater than SIZE of PP2 (SIZE of MATTER is indeterminate; therefore always fulfills criterion)	wine ↑ wine <=IN=> knapsack
CONTAINMENT RECIPROCAL containing with...in it		knapsack containing wine car with map in it		knapsack ↑ wine <==IN==> knapsack
POSITION ADJACENT on top of . . . . . on bottom of . . . at on left side of right on front of . . . . on back of . . . . on	 ONTOP ONBOTTOM ONSIDE ONFRONT ONBACK all of above	dancer on table	PP1 = +PHYS PP2 = +PHYS and not INST and SIZE of PP1 not greater than SIZE of PP2	dancer ↑ (ON : ONTOP) dancer <======> table

Figure 4-1

Note 1 - There are several ways of being ON, depending on which part of PP2 is involved.

Note 2 - For needs other than those of a parser, 'left', 'right', etc. might map into ONLEFT, ONRIGHT, etc. rather than into the more general ONSIDE. This applies analogously to the following example.

Note 3 - If we want to exclude very unusual situations ('elephant on ceiling'), we need more specific semantic descriptions and tests and some world knowledge (as to objects which can "cling"). E.g. a 'room' is a "topological inverse" of a box; the top of the room (ceiling) is really a "bottom" as far as the ability to be on it (without falling) is concerned. In any case, we must at least include the information that a 'wall' is a PART which is a <u>SIDE</u>; a 'cover' is a PART which is a <u>TOP</u>, etc.

POSITION				
NON-ADJACENT				
above	ABOVE	sun behind mountain	PP1 = +PHYS PP2 = +PHYS	sun ↑ (POSN . BACK) sun <=========> mountain
over				
below	BELOW			
under				
beneath				
to left side of	SIDE			
at right				
on				
beside				
in back	BACK			
behind				
on other side of				
in front of . . .	FRONT			
at				
before				
PROXIMITY				
near (to)	NEAR	sun near mountain	PP1 = +PHYS PP2 = +PHYS	sun ↑ (PROX . NEAR) sun <=========> mountain

Note = This is an example in which actual world knowledge would be a hindrance. According to our visual perception, we can speak of the sun being near a mountain, even though it is inconceivably far away.

Figure 4-2

BOUNDARY along alongside (of) around surrounding about	ALONG AROUND	trees along wall trees around house	PP1 = PLURAL or +1D PP2 = +1D or ENV or PP2 = +PHYS and ENTITY	trees ↑ ALONG trees <=====> wall

Note - We are assuming the existence of "PLURAL" as a boolean function or flag.

Dominance Relations:

INALIENABLE PART of	IMPART	tip of ski	PP1 = PART PP2 = object of which PP1 is specically a part	tip ↑ IPART tip <=====> ski
INALIENABLE PART RECIPROCAL with having		ski with tip		ski ↑ IMPART tip <=====> ski

Note - Here we see the English syntactic equivalence between 'ski tip' (noun-pair) and 'tip of ski'.

ALIENABLE PART of	APART	buttons of coat	similar to criteria and representation for corresponding noun-pair (Figure 3-1, PART_AL)	
ALIENABLE PART RECIPROCAL with		coat with buttons		
ALIENABLE POSSESSION of with	APOSS	glasses of man	PP1 = +PHYS and not +ATT PP2 = HUMAN or ANIMAL	glasses ↑ APOSS glasses <=====> man
ALIENABLE POSSESSION RECIPROCAL with		man with glasses		man ↑ APOSS glasses <=====> man

Figure 4-3

OWNERSHIP belonging to owned by of	OPOSS	land belonging to people	PP1 = +PHYS PP2 = HUMAN	land ↑ OPOSS land <=====> people
OWNERSHIP RECIPROCAL with owning		people with land		people ↑ OPOSS land <=====> people
DESTINATION (destined to be possessed) for intended for	APOSS OPOSS	slingshot for Dennis	Criteria depend on whether possession is to be physical (APOSS) or social (OPOSS)	slingshot ↑ FOR APOSS or OPOSS slingshot <======> Dennis

Note - A conceptual "FOR" - or purpose-link is introduced here and is a necessary basic concept for conceptual representation in general.

QUANTIFICATION of		mug of beer	PP1 = +P[illegible] (FN: contain) PP2 = MATTER or (PLURAL and SIZE of PP2 not greater than SIZE of PP1)	suggested: beer ↑ (1) mug (20 oz., etc.)
DESCRIPTION		movie about mushrooms	PP1 = INF PP2 = PP	see DESCRIPTION in Figure 3-5

Figure 4-4

to make some theoretical observations on linguistic analysis of the more general concepts involved. The concepts involved in the representations are basic ones (source-goal, physical, abstract and social dominance, inherent properties, conceptual relationships between action, events and objects, function and instrumentality) and are designed to fit into a systematic theory of conceptual representation, that is, one which by virtue of the human-oriented universality of its component concepts is language-independent. One can of course not deny that any semantic representation system will tend to be biased in favor of the linguistic and conceptual experience of the author. However, such a system, apart from its immediate applicability to the language or language family in which it is conceived, can serve as a starting point for consistency with other languages to which somewhat different representations and semantic criteria may be better suited.

Although the semantic theory presented is certainly subject to extensions and revisions, it does include an attempt at a specific formalization of semantic properties. This is a question avoided by Katz and Fodor in their specification of the requirements for the structure of a semantic theory (4). We should perhaps make a few comments on their treatment of the representation of semantic information as it relates to our system. However, we would first like to note that our semantic category system, operating in the context of the conceptual dependency parser, satisfies the requirements which Katz and Fodor postulate for a semantic theory, as far as parsing is concerned: Besides disambiguation capabilities, it has the ability to detect semantic anomalies such as 'silent paint'; it is consistent with the conceptual dependency theory's concern with recognizing paraphrases (i.e. of mapping various equivalent lexical expressions into the same language-independent representation), in that it applies this capability to lexical and conceptual prepositions.

We agree with Katz and Fodor that there should be a relatively small number of semantic markers or features (and thus of categories), at least for the purpose of machine understanding, which is our chief interest. However, Katz and Fodor

do nothing to ensure that this will be the case. By enlisting categories such as "aesthetic object" as they are needed, without attempting to define and put into context the term "aesthetic" so that it can be generally referred to outside of their specific example, Katz and Fodor run the risk of a very open-ended marker-category system. They do not suggest any specific method of concept analysis to handle the thousands (?) of such categorical phrases found in conventional dictionaries. This problem stands in spite of their claim that the markets "reflect systematic semantic relations".

To pursue their 'colorful ball' example, our system would determine the readings of this phrase in the following way: First the lexical item 'colorful' would be found to be defined in the dictionary by the conceptual representation of 'having (as an abstract attribute) much (or many) color(s).' It would then be noted that 'color' applies to any PP with the +PHYS feature (or alternatively, any form of matter), as well as to 'light' itself. Since the senses of the PP 'ball' are either POBJ or EVENT, both of which implicitly have a +PHYS component, we accept all of those dependencies in which 'colorful' means essentially 'full of color'. (The complete sentence 'The man hits the colorful ball' is then disambiguated by noting from the verb-ACT-dictionary (8) that the object of 'hit' can only be a +PHYS ENTITY or MATTER, thus eliminating 'ball' in the EVENT-sense.) Katz and Fodor consider also the metaphorical sense of 'colorful': 'having distinctive character, vividness, or picturesqueness', such as perhaps applies to personality or imagination. Our approach to metaphor in general, seen as deriving from a basic. ly physical world as we have described it, will be indicated in a future paper (6). It will not be the treatment of Katz and Fodor, who make no attempt to recognize metaphorical relationships between certain "senses" of a word. Instead we will rely on further semantic analysis to determine common elements of a word which has received an apparent "extended sense". For instance, we can surmise that 'colorl.. imagination' means something like 'much imagination' on the basis

of the 'much'-component of 'colorful'. Conclusions drawn on the basis of such scanty information will not always be satisfactory, nor will they handle all the nuances of linguistic expression. However, the important point is that many of the more critical problems involved in computer understanding can be resolved with relatively simple information which is intuitively clear to anyone who wishes to experiment with and further develop this system.

We should make a few remarks on our system with reference to the assertion that "distinguishers" as Katz and Fodor define them must be included in the semantic component at all. Our features are comparable to Katz and Fodor's markers in that we depend on these features to resolve ambiguities. We have no counterpart to distinguishers, which in Katz and Fodor's own terms are the part of meaning 'of which a semantic theory offers no general account'. This does not mean that we stop our semantic descriptions at the specification of a feature configuration. What we do is fill in "slots" which we know (as part of the theory) to be applicable to the item in question by virtue of more general feature information. In every case our decision as to what is relevant to an item is guided by the use of this information in understanding a dependency involving the item.

Bolinger (2) considers several approaches to the distinguishers of Katz and Fodor. His attempt to follow up Katz and Fodor's system by formalizing distinguishers ends with such detailed, redundant or unmanageable "markers" as (Phocine) and (Nonbecoming). He suggests that Katz and Fodor have kept the marker-distinguisher dualism in the realization that such additional markers complicate rather than solve the problem. The idea (expressed with some doubts by Bolinger) that distinguishers could perhaps reflect "knowledge of the world", as distinct from knowledge of language, corresponds roughly to our distinction between cultural experience and conceptual knowledge, or "innate" knowledge or conceptual properties and relations which enter into language. We have tried to exclude cultural experience from our system in the interests of universality and (specific-) language independence,

except insofar as the filling in of a slot as described above helps to define the immediate meaning of a word. (Katz and Fodor do not seem to consider distinguishers as reflecting world knowledge, insofar as they themselves state that such knowledge is beyond the bounds of a semantic theory, whereas distinguishers supposedly have a role in the theory.)

There is also evidence to show that in language understanding we simply do not need to depend on knowledge of the world (or on "distinguishers") to any significant extent. We might say that the primary task of our semantic component is to aid the parser in arriving at the correct conceptual structure of an input sentence fragment on the basis of semantic information. This involves helping to decide the correct conceptual categories of the items involved. The secondary task would be to choose a sense out of all the senses falling into this conceptual category, or, in the case of nominals, falling into the same major or even minor PP-category. (The second problem will at times be solved through the solution of the first.) We have attempted to show that only conceptual information ("marker-level") is necessary for the primary task. The second task becomes critical in the case of e.g. Bolinger's 'Henry became a bachelor in 1965'. The question is, how far should the semantic component aid in interpreting this sentence and to what extent must "distinguishers" or world knowledge be involved?

At present, the semantics programs are referenced to only in the matter of qualifying dependencies, whereas the above example is predicative with respect to the relation between 'Henry' and 'bachelor'. However, the capability to deal with this type of interpretation is present in the theory. In the face of the "equivalence" or "set-membership" conceptual link ('become' is of this category (6)) between 'Henry' and 'bachelor', it is noted that 'bachelor' should be HUMAN, as 'Henry' is. We must, however, keep in mind that in sentence analysis we must be prepared to accept any interpretation for which we can determine a valid conceptual structure, if there are no other alternatives available. Thus we would

accept 'The frog became a prince' (which is fortunate if we are concerned with fairy tales) and 'Henry became a book' (which is less fortunate but offers no alternatives). Both of these interpretations could be marked as "strange", of course, on the basis of the observable change of category.

Excluding 'seal' leaves three interpretations of 'bachelor' to be considered. At this point we should note that statements in the "real world" are rarely given in complete isolation, as they are in linguistics articles. Katz and Fodor state that 'a theory of semantic interpretation is logically prior to a theory of the selective effect of setting'. However, this is true only if the set of alternatives provided by the semantic theory is not too narrow. Setting or context should not be relegated to last place in the decision process, but should take priority over considerations of "usualness". A parsing program would look at the context of the sentence before making any choice between conceptually acceptable alternatives. Although upon seeing the above example in isolation, a human might choose the sense of 'with a bachelor's degree', on the basis of cultural information, it is possible that in context any one of the senses of bachelor could already be established in the paragraph under consideration. That these other senses are conceivable to begin with might be argued in several ways. For instance, Henry may become an unmarried adult male if prior to this time he was too young to be considered as a bachelor anyway. However, even assuming Henry is an adult, one might produce 'became a bachelor', meaning in a sort of literary or facetious style "returned to an unmarried way of life". In fact, this sense is so much more familiar to most people than the other meanings (especially the 'knight'), that a hearer might subconsciously sense: 'Your sentence is anomalous, but I understand what you want to say'.

Assuming that context does not provide any useful information, we are still left with the undesirable 'knight' sense (although it would be simple

in this case to list this sense with the lowest priority in the dictionary due to its relative lack of frequency. We must admit that 'in 1965' provides a useful clue if we have the information that knighthood died out many years ago. However, to incorporate such culture-specific information in our semantic component (which supposedly represents a hearer's linguistic capabilities) is, to use Bolinger's terms, like looking through the wrong end of a telescope. To retrieve such information we need a vast formalized body of knowledge together with referral mechanisms--a question-answering system in itself. Although such information will eventually be needed in order to completely simulate human understanding of communication, we deem the cost of merely adding to the assurance that we have chosen the correct sense of a word too high in the face of other aids to interpretation. A similar situation holds for the description of the 'knight' sense of 'bachelor' itself. Katz and Fodor's distinguisher 'serving under the standard of another knight' and probably also any distinguisher which they would propose for the word 'knight' are relatively unimportant to parsing, since knights and bachelors are conceptually capable of anything that any HUMAN is. In summary, there is a use for non-conceptual or incidental information, but it can and should exist independent of and subordinate to our semantic system, rather than be incorporated into it.

In the light of this division between the two types of knowledge, all our features represent conceptual rather than cultural knowledge. The features generally satisfy the criterion of being "inherent" properties rather than unstable situations or conditions. We might say in Bolinger's terminology that our semantic descriptions are generally "substantive" rather than "constructive" definitions. We concentrate on "hard objects" and objective properties, which are what yield conceptual information.

The decision as to whether a certain characteristic of a concept should

be admitted as a feature is not always simple. For example, it might seem that "domesticity" is important enough to be a feature ($\pm$DOMESTIC): It helps us to distinguish the different meanings of 'dog coat' and 'leopard coat', since domestic animals or pets in being treated as humans might conceivably wear coats. Yet domesticity is a cultural condition rather than a conceptual feature. We want to restrict our admission of conceptual features (and thereby of categories) as far as possible. However, there is nothing to prevent us from entering such information as specific data relating to ANIMAL, in the way that e.g. FUNCTION relates to a +MM object. Thus the "class" of the animal could be 'pet', 'domestic' (but not a pet) or 'wild', with of course the possibility of variability between these classes. We accept such information into our semantic descriptions because it has an influence on the "role" of an animal, potentially assigning it some human-like behavior. In the light of the balance between descriptive power and economy, we would not accept information such as "phocine-ness", since such information has very limited applicability to the determination of semantic dependencies.

7. Conclusion

The semantic category system we have outlined represents an attempt in the direction of profitably systematizing conceptual dependency rules and semantic descriptions of the objects involved. Dealing at the conceptual rather than at any syntactic or "deep-structure" level, it relies on semantics and its role in determining dependencies and thus attempts to be language-independent. Such a system together with computer experimentation with it could lead to a better understanding of the definition of the "conceptualization" and lays a basis for a more rigorous treatment of conceptual relations at higher levels. In addition to lending itself to the solution of problems concerning consistency of semantic descriptions of nominals, the system (with its emphasis on components of meaning) is suitable for carrying on further analysis as to how we grasp the meaning of language. This is a step towards achieving a "valid" sort of computer understanding of language.

Appendix

The chart of Figure 5 depicts the three groups of categories of nominals as suggested in Section 3.2. The dependencies which apply to each category, as well as those which apply to specific examples within each category are entered in the appropriate "slot" in each "dependency column". In other words, the chart gives the PA-, ACT- and the various types of PP-dependencies on the concepts listed at the left. We refer to the concepts at the left as the "independent" ones, insofar as they are the PPs which are the "topics" of the phrase in question. The semantically described concepts in the matrix itself represent the "dependent" PPs, i.e. those which have a qualifying role in the phrase. Thus 'y in row x, column a' means y is "a-dependent" on x. We emphasize this definition in order to avoid confusion with physical dependence as expressed by the nature of the dependency itself. For example, in the 'the color of the flower', 'color' is physically dependent on 'flower'. There are some selectional restrictions which appear opposite a category rather than a specific concept at the left; indicating that these criteria apply to all items of the category, apart from any criteria applying to each individual concept.

For groups I and II, the entries for PA- and ACT- dependencies, where they exist, will in general consist of one of a few very basic PAs or ACTs. The PAs are themselves given in nominal (ATTRIB) form, e.g. 'amount' rather than as 'large, small', and only the primitive ATTRIBs 'amount' and 'existence appears in the PA-column in Figure 5. Similarly, only the basic ACTs involving change in magnitude ('chmag') and change of place ('move') occur in the column headed ACT. The entries for the PP-dependencies, when they occur, refer to the category of, or semantic restrictions on, the dependent PP as established in Section 3.3.

In group III, the PA-dependencies on ENTITY are given simply as '<ATTRIB>'. This means that information on PA-PP dependencies will be given from the point of view of the ATTRIB corresponding to the PA, rather than from the point of view

of the PP. For example, 'red flower' will be checked by looking under 'color' and seeing whether 'color' can be an (abstract) IPART of an item which is consistent with the semantic description of 'flower'. The semantic descriptions of PPs dependent on ENTITYs (as well as STATE:-information for PHENs) are given in the PP-dictionary and referred to in the preposition- and noun-pair- programs as discussed in Section 5. The "PAs" dependent on EVENTs are AAs, or ACT-assisters (7), which will not be discussed here.

The chart is meant to give an overview of some of the conceptual relationships which hold between the various categories of concepts. It is not meant to imply an implementation which necessaril isolates this information from the semantic dictionary described in Section 4 or from semantics subprograms oriented to the type of problem to be handled. For instance, it has already been indicated that the PP-PP relations for ENTITYs are treated in the preposition- and noun-pair-sementics subprograms. These programs could and probably should handle PP-PP dependency information for concepts of every nominal category, with of course the aid of access to the PP-dictionary. Likewise, a PA-subprogram would handle all PA-dependencies. (The PP-dependencies on ATTRIB, which consist mainly of IPART, would be included in the semantic descriptions of the ATTRIBs in the PP-dictionary.) Non-functional-ACT information is generally found in the ACT-dictionary (8), where it can be referenced directly by the parser.

It might be noted that this matrix contains some systematic information which might be of use to a PA-semantics subprogram. The categories given represent different levels of definition of an object. For instance, MATTER, e.g. 'plastic', which is an attribute of an object but also can exist independently of a recognized object, can receive the QUAL attribute 'red'. 'Red' as an instance of the 'color' QUAL attribute can receive the QUANT attribute-value 'bright'. This information can be obtained from the matrix, because one of the PP-PP dependencies (columns) which must be considered for each major category is "inalienable at-

tribute of ____" (IPART), for which slot the proper category or item is entered. Thus whether we encounter 'bright red plastic ball' or 'bright ball', we know in both cases that 'bright' applies throught a short chain of properties to the item 'ball'. We do not consider 'bright' as a property which ad-hocly applies to 'color' (or 'light'), MATTER and the object-class to which 'ball' belongs. The result is a more intuitively valid model, and some economy in space and time in the semantic component.

CONCEPTUAL-ATTRIBUTE-BASED CLASSIFICATION of NOMINALS

DEPENDENCIES:	PA	ACT	PP (IPART)	(APART)	(APOSS)	(OPOSS)	(PROX)	(POSN)	(AT)	(IN)	(ALONG
PPs											
I BASIC	existence (free, occupied) amount	chmag	-	-	+ANIM	HUMAN	specf (see specific examples)	specf	-	specf	-
$space_1$							$space_1$, +PHYS	$space_1$, +PHYS		$space_1$, +CONT	
$time_1$							$time_1$, EVENT	$time_1$, EVENT		$time_1$, EVENT	
II MATTER <(certain) ATTRIBs>	amount	chmag move	ENTITY +PHYS	-	+ANIM	HUMAN	$space_1$, +PHYS	$space_1$, +PHYS	-	$space_1$, +CONT	?
rubber											
(ACTION)	<AAs>	-	-	-	-	-	-	-	-	-	-
PHEN	amount ATTRIBs>	chmag STATE:	-	-	-	-	$space_1$, ENV specf SIZE	$space_1$, ENV specf SIZE	+ENVMT	+ENVMT specf SIZE	+1D
light		shine					≥ 1	≥ 1		≥ 1	
rain		fall					$\geq$	≥ 1		≥ 2	
ATTRIB											
QUANT	amount	chmag	specf	-	-	-	-	-	-	-	-
width			ENTITY +PHYS								
density			+PHYS, PHEN								
brightness			light, color								
QUAL	-	-	specf	-	-	-	-	-	-	-	-
shape			ENTITY +PHYS								
texture			MATTER								
color			light, MATTER								
SPEC	-	-	specf	-	-	-	specf	specf	-	specf	-
location			$space_1$, +PHYS				$space_1$, +PHYS, LOCATION	$space_1$, +PHYS LOCATION		$space_1$, +CONT, MATTER	
$time_2$			$time_1$, EVENT				$time_2$, EVENT	$time_2$, EVENT		$time_1$, EVENT	

Figure 5-1

(cont.)	PA	ACT	PP (IPART)	(APART)	(APOSS)	(OPOSS)	(PROX)	(POSN)	(AT)	(IN)	(ALONG)
ATTRIB$_{+ANIM}$											
TRAIT	+amount	chmag	+ANIM	-	-	-	-	-	-	+ANIM	-
wisdom											
III ENTITY	<ATTRIB>	(ACT-DIC)	---	P R E P O S I T I O N and N O U N - P A I R S E M A N T I C S ---							
EVENT	<AA>	-	-	-	-	-	EVENT, LOCATION, +PHYS	EVENT, LOCATION, +PHYS	EVENT, LOCATION, +PHYS $\geq$ SIZE of physical aspect of EVENT	space$_1$ +CONT $\geq$ SIZE of physical aspect of EVENT	+1D specf

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